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Spatial Multi-Criteria Analysis for Urban Sustainable Built Up Area Based on Urban Heat Island in Serang City

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Abstract. The rapid of human occupancy in Serang City has caused the development activity of the built-up area increased significantly. Increased development has led to the phenomenon of Urban Heat Island (UHI), namely the increase in air temperatures in the Serang City that threatens the survival of society. Meanwhile, at the same time, Serang City is urged to keep doing development to provide land for community activities. Against this background, spatial analysis is needed to determine the development of built-up area based on the principle of sustainability. Regional modeling of sustainable area development based on sustainability in Serang city can do by using SMCE (Spatial Multi-Criteria Evaluation). The various criteria covering UHI distribution, distance from the road, distance from the river, land use data, and physiographic data were processed by specific weighting so that the resulting suitability area of the built-up area. The distribution of UHI in Serang City agglomerated in the center of Serang City with the highest surface temperature value of 32^0C. Meanwhile, through the SMCE modeling results, the region's suitability area of 3.313 Ha was established which distributed at several points in Serang City and spread linearly following the road network with the extended area of 3.538 Ha. Meanwhile, the central, north, and west of Serang City area dominated by unsuitable for a built-up area with a total area of 19.553 Ha.

1. Introduction

The ratification of integrated economic zones in the ASEAN region (AEC/ASEAN Economic Community) has led to the formation of a single production and market base for ASEAN member states, including Indonesia. This regional cooperation led to the creation of a free market in the areas of the capital, goods and services, and labor. The impact can be felt mainly in the acceleration of the flow of goods and services, free flow of services, investment, and the free flow of capital. The consequence of all that is the acceleration of economic growth through various development activities.

Serang City is one of the growth centers in Banten Province. In a macroeconomic perspective, one of the indicators to determine the magnitude of economic growth is the level of investment absorption. Realization of investment in Serang City at the end of July 2016 reached Rp 1.98 trillion, which increased sharply when compared to last year in the same period. The investment value of Serang City from year to year has increased [1]. The largest sector of investment value in Serang City dominated by trade, services, and property sector, and housing and retail sector [1].

The significant increase in investment value in the property sector from year to year shows that the development of the built-up area in Serang City is very high. However, this phenomenon also contributes to new problems in the perspective of space and environment. Increased property development (housing and retail) indicates the higher amount of built-up area in Serang City. Massive community activities also exacerbate the quality of space and the environment. This impact on the formation of urban heat island (UHI) as the phenomenon of urban hot pole due to uneven heat excess [2]. UHI has vital implications for human life, especially about human comfort, urban air pollution, energy management, and urban planning [3]. UHI phenomenon in the city can lead to higher energy use to cool the air, increase human discomfort, and cause air pollution concentration.

Voogt [2] says that surface characteristics and atmospheric conditions can influence the formation of an urban heat island. UHI phenomenon itself can be exacerbated by human activity, from now on referred to as anthropogenic heat. Therefore, UHI causes can be natural causes and anthropogenic causes. The causes are explained in more detail by Iswanto [2] as follows:

1. Surface geometry. Surface geometry means the obstruction of the sky by buildings and other objects on the urban surface expressed as a sky view factor. The addition of surface geometry and trapping of solar radiation by multiple reflections triggers heating due to greater sunlight absorption. The effect of sheltering effect can occur and reduce the convective heat loss from the surface and air near the surface due to the existence of this surface geometry
2. The surface thermal property. It is undeniable that the condition of the surface material dramatically influences the importing and discharging process. Solid and wet materials such as metals, stones, saturated clay soils, which are common in urban areas, are straightforward to absorb and release heat that causes massive UHI phenomena.
3. Surface conditions. Water-resistant urban building and paving reduce evaporation; More energy directed to a sensible heat that can heat air than latent heat (heat taken for water evaporation).
4. Anthropogenic heat. This heat generated from human activities, such as the use of an Air Conditioner (AC) is excessive.
5. Urban greenhouse effect. The polluted and hotter urban atmospheres release excessive thermal radiation downward toward the city's surface. Increased city humidity can also contribute to this effect.
6. Wind and cloud. Wind and cloud conditions determine the formation of UHI. The bright sky can improve cooling by easing the radiative heat loss from the earth's surface. Even increased wind speeds can lead to turbulence that reduces air temperatures near the surface.
7. Advection. Advection plays a role in moisture formation and turns it into a cooling process that reduces heat island intensity.

The existence of UHI cannot separate from the pattern of land cover changes, such as vegetation composition, water, and land changes [3]. In the study of urban climatology, urban development usually brings enormous changes to the surface of the earth. Urban development can trigger the formation of the temperature contrast between urban and rural area. Natural vegetation replaced by built-up land will cause the redistribution of solar radiation on the earth's surface disrupted. The build-up causes the contrast of surface radiation and air temperature in urban areas.

However, it cannot deny that the use of land for the construction of the built-up area in Serang City still needed considering economic growth. Therefore, spatial analysis is needed to determine the right built up area considering sustainable aspects such as society, environment, and economy. Spatial Multi-Criteria Evaluation (SMCE) modeling is a method based on a geographic information system that can be used to determine the built-up area in Serang City based on sustainable aspects. SMCE is one of the methods in the decision-making process (spatial decision support system) in regional planning using a simulation model with several criteria and factors [4]. This modeling can lead to the right area for the development of the built-up area by taking the economic, community, and environmental aspects simultaneously so that the developer capable of triggering UHI phenomenon can be reduced as much as possible without reducing the basic purpose of the development itself.

2. Methodology

2.1. Flowchart Work

Research begins by determining the modeling criteria variables that divided into spatial factor and spatial constraint criteria (**Figure 1**). River and road are the variables used in the spatial factor. While the land use, slope, and UHI distribution are used as spatial barriers and included in the spatial constraint where the built-up area is not possible to built-in undue territory based on sustainable principles. Spatial factor and spatial constraint are performed to form the suitability area for the built-up area.

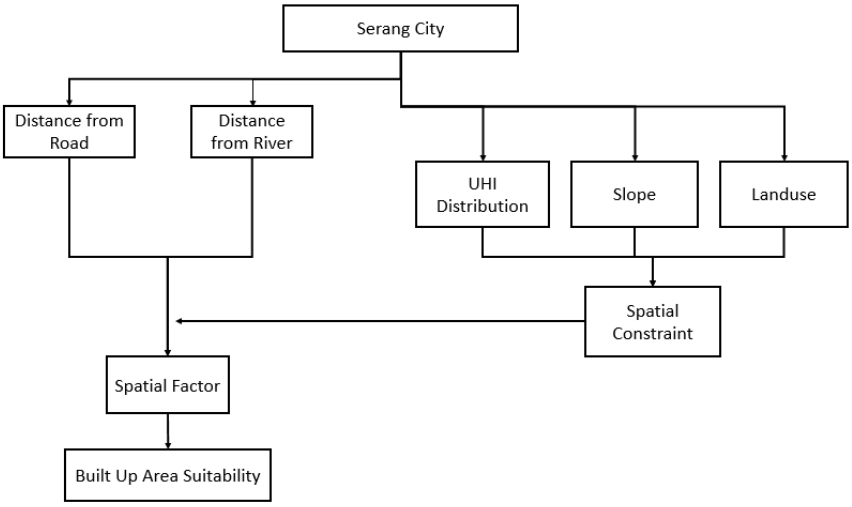

Figure 1. Flowchart work

2.2. Data Processing

2.2.1. UHI Distribution.

UHI phenomenon obtained from imagery processing of band 10 Landsat 8 to know the value of LST (land surface temperature). However, before looking for LST value, Landsat 8 image must be corrected. There were two corrections performed in this study:

1. Radiometric Correction

   Error or radiometric defects, that was errors in the form of shifting values or degree of gray image elements (pixels) in the image, to approach the price that should be [6]. Radiometric errors can be caused by errors in optical systems, errors due to electromagnetic radiation energy interference in the atmosphere, and errors due to the influence of the sun's elevation angle.

2. Geometric Correction

   Satellite orbit was very high, and the field of view is small, then geometric distortion occurs. Based on the source, distortion or geometric error can group into two types, namely internal errors and external faults [6].

After the imagery was corrected, then the image was processed to get the LST value in Serang City. Processing conducted with the steps following as:

1. First, the Digital Number (DN) Landsat 8 band ten satellite imagery converted to spectral radiance value with the following formula:

$$L\lambda=(M\times DN)+A \quad (1)$$

   In which, Lλ is spectral radians (wm-2sr-1μm-1), M is the value of digital number Multiplicative band 10 (obtained from metadata), DN is a digital number band of 10 Landsat 8, and A is the value of the spectral increase of radiance in band 10 (obtained from metadata).

2. Second, the value of formula one was processed to obtain LST value with the formula:

$$T=K2/\ln((K1/L\lambda)+1) \quad (2)$$

   Where T is the temperature of the satellite sensor (Kelvin), K1 is the calibration constant 1 for Landsat 8 (derived from metadata), K2 is the calibration constant of 2

Landsat 8 (obtained from metadata), and Lλ is the ten bands Landsat 8 band spectral obtained of equation 1.

3. Third, the conversion process of LST value from Kelvin to Celsius unit using formula:

$$LST(celcius) = T - 272.15 \quad (3)$$

2.2.2. SMCE Model.

SMCE is one of the methods in the decision-making process in regional planning using a simulation model with several criteria and factors [4]. In the geographic information system (GIS) modeling, SMCE is one of the most useful analysis as a management information system specifically designed to support planners and stakeholders in decision-making related to regional development and planning. This SMCE modeling utilizes software ILWIS (Integrated Land and Water Information System) 3.3 developed by ITC Netherlands. The variables used in this study adjusted for the type of criteria covered by spatial factor and spatial constraint criteria. The SMCE model was created by referring to several requirements and standards that behave in Indonesia. These requirements saw in **Table 1**.

Table 1. Conditions for the feasibility of built-up areas

Requirements	Sources
The road network that serves the primary artery is a maximum of 250 meters	Technical guidelines for industrial estate development in the regions - Ministry of Public Works and Housing [12]
Land topography / slope max 0 - 15 degrees	Technical guidelines for industrial estate development in the regions - Ministry of Public Works and Housing [12]
Allocation of non-settlement and non-agricultural land	Technical guidelines for industrial estate development in the regions - Ministry of Public Works and Housing [12]
At least 15 meters from the left and right bank of the riverbed along the river channel	Government Regulation (UU)S No. 38 of 2011 on the River [11]
Not including UHI polar regions	-

The first spatial constraint is land use, assuming that the built-up area will not be built in swamp areas, settlements, swamp forests, and forests that function as green areas. Thus, the standardization process for the land use data is as follows:

1. True value
   a) Types of land use that may build in the built-up area.
   b) Criteria included in the calculation (value 1)
2. False value
   a) Types of land use that cannot build in the built-up area.
   b) The criteria included in this category automatically excluded from the calculation (value 0).

Then, based on Technical Guidelines for Industrial Estate Development in the Ministry of Public Works and Housing [12], the construction of the built-up area will be adjusted to the appropriate physiographic condition. Built-up areas will suitably be constructed on relatively flat and unsuitable topographic conditions built on steep slopes to apply standardization:

a) 0-5% is True
b) 5-15% is True
c) 15% is False

The last spatial constraint factor criterion is UHI distribution. In this context, it assumed that built up area development would be avoided at the UHI polar regions in order to suppress and not aggravate the number of UHI phenomena in these areas. Therefore, in this criteria apply standardization:

a) Non-UHI area is True
b) UHI area is False

Bukhari *et al.* have explained the influence of distance from several points of interest as input in SMCE modeling [10]. On the road data criteria, the location of the built-up area at least must less than 250 meters from the road to ensure accessibility. Therefore, the standardization of this data conducted by using the cost principle which the closer the location to the road and the value of the location was more suitable.

Meanwhile, based on Government Regulation (UU) No. 38 of 2011 Refer River [11], the physical building boundary of the river must be at least 15 meters from the left and right along the river channel. Therefore, the standardization of distance data criteria from the river network was done using the benefit principle, the closer to the riverside the lower suitability value. The next step was to weigh the individual criteria through the simulation process with equal weight (equal) for each spatial factor criteria.

3. Result and Discussion

3.1 UHI Distribution in Serang City

Distribution of UHI phenomenon in Serang City can see by looking at the LST value (land surface temperature) from band 10. The result of LST value from this processing indicates that UHI phenomenon in Serang City agglomerated in a central area of Serang City (CBD area) which was dominated by the usage typical urban land use such as office buildings, housing, and industry. Meanwhile, suburban areas that dominated by natural vegetation land cover show no increase in temperature or absence of UHI. UHI phenomena in Serang City are characterized by an increase in surface temperature (LST) of up to 32^0C, while The lowest surface temperature of 250C characterizes UHI-less areas. Distribution of the UHI phenomenon in Serang City seen in **Figure 2**.

The linkage between land cover and the UHI phenomenon itself have explained [2][7]. The concentration of UHI phenomenon in Serang City that occurred in the CBD area shows that the dominance of the built-up area has a close relationship with the formation of UHI [8][9]. The concentration is following with Adiyanti's research [2] in Jakarta which found that the air temperature profile in Jakarta shows the highest temperature value in the CBD area and the air temperature profile in Jakarta shows the influence of land use type, vegetation, and building density. Singh research [14] in Central India which also made temperature profiles based on land use types found that industrial zones have the highest temperatures followed by densely populated urban centers, newly opened settlements, wet rice fields and vegetation on wetlands, and water. These indicate that the correlation between the UHI phenomenon and the type of land cover is quite significant. Therefore, it is very important to plan sustainable development based on sustainable development so that the threat of the UHI phenomenon could be suppressed.

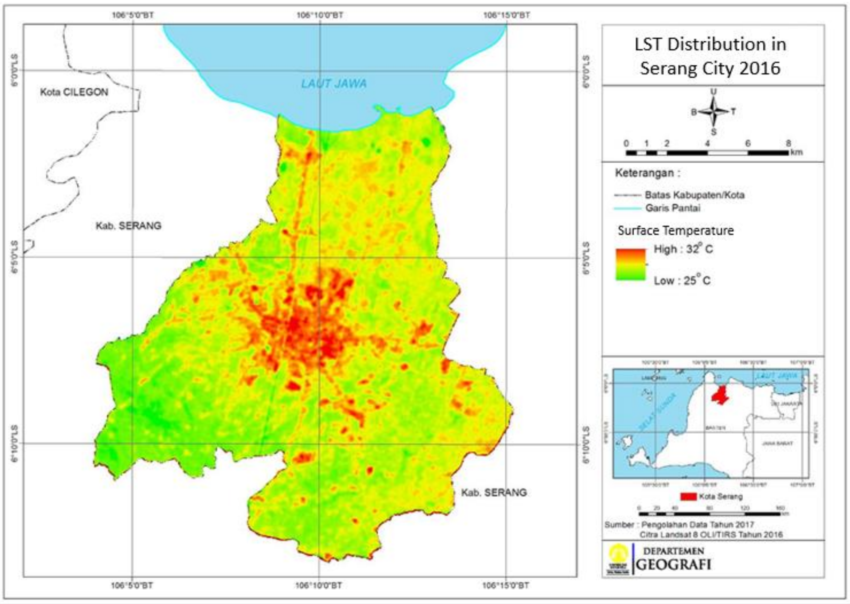

Figure 2. LST Distribution of Serang City in 2016

3.2 SMCE Simulation Result

The simulation process in this research was conducted by determining the selected criteria factors and giving weighted to each criteria factor with the same weight. The principle of equal weighted from the principle of sustainable consideration, in which the principles of society, economy, and environment treated on a balanced scale. In this simulation, the researchers gave the same weighting for the ecological criteria factor (distance from the river network) and the economic criteria factor (distance from the road network) by 50%. For land use factor, UHI distribution, and slope data, all of which included in the spatial constraint criteria. These three data are automatically eliminated in the weighting process because the weighting value is zero (0). The weighted result with SMCE for simulation itself can see in **Figure 3**.

The spatial distribution of red areas indicates that the area is unsuitable (0) for the built area, a spatial distribution of yellow areas indicating the area is moderate suitable, and the spatial distribution of green areas indicates the suitable location (1) for a built-up area. Meanwhile, according to **Figure 3**, the moderate suitable area was seen to agglomerate in the south and southwest Serang City. Roughly, the distribution of a suitable area in Serang City appears to be random. In the southern part of Serang City itself, the suitable area is dominated linearly following the road network. The road network indicates that the development of built-up area considers the road network as accessibility advantages. Agglomeration of the region according to this area also occurs due to the UHI phenomenon. The exciting thing is that there are several points of a suitable area located around the highway road so that it is a very potential area for development.

Areas that not suitable for the construction of the built-up area dominate in this modeling with an extent of 19.553 Ha. The area is not particularly suitable in central Serang City which is the center of UHI poles. The northward and westward of Serang City dominated by conservation land use and residential area. The northern area of Serang City generally dominated by conservation areas, such as ponds, swamp forests, and forests, so this area is not allowed to build. The distribution of unsuitable area also located in areas with steep physiography (> 15%) and looked like a red block in the southwest of Serang City in **Figure 3.**

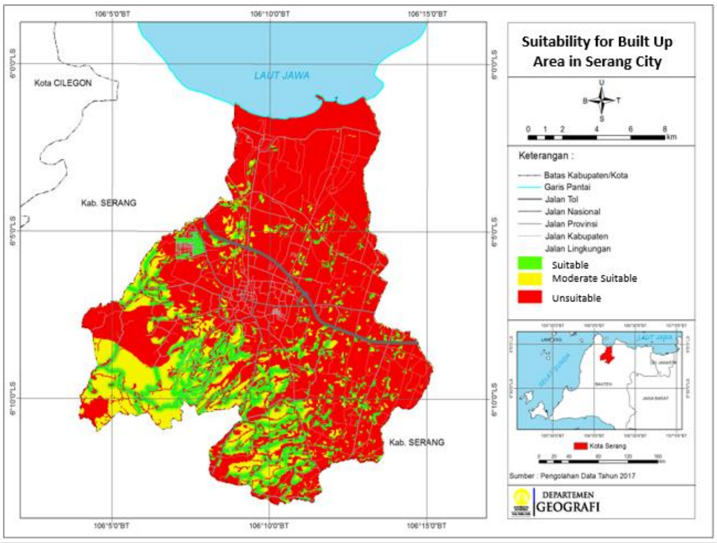

Figure 3. Suitability of built-up area based on UHI in Serang City

The area for each classification for the suitable areas, moderately suitable areas, and unsuitable for the development of the built-up area can see in **Table 2**. From the table, we can know the ratio of the area of each classification of the built-up area suitability in Serang City. The area that is unsuitable for the construction of the built-up area dominates the overall conformity area and followed by successively appropriate areas and suitable area for the construction of the built-up area.

Table 2. The extended area of each classification

Area Classification	Extent (Ha)
Suitable	3.313
Moderately Suitable	3.538
Unsuitable	19.553

While referring to Serang City Pattern Plan 2010-2030 contained in Serang City RTRW, the potential and appropriate area for the development of the built-up area in Serang City is the area included in the zoning of Trade and Service Zone. Thus, the potential area for the development of the built-up area in Serang City is the area belonging to the area according to SMCE and Trade and Service zone modeling in the Spatial City Pattern Plan (RTRW) Serang 2010-2030 [13].

4. Conclusion

Spatial Multi-Criteria Evaluation (SMCE) can be used to analyze the suitable area for the built-up area in Serang City based on several criteria, including of UHI phenomenon. Determination of simulation model with a sustainable principle done by performing equal weighting on each factor so that obtained value and spatial distribution from the appropriate area and suitable for the development of the built-up area in Serang City.

Based on the results of this model, the suitable and moderate suitable for the built-up area in Serang City spread in the southern and southwestern regions with a linear pattern following the road network. The unsuitable area dominates the central, northern and western regions of Serang City due to the concentration of UHI phenomenon in the center region, settlement land use, and conservation areas.

The suitable area for a built-up area in Serang City, referring to the Serang City Plan Pattern, lies in the KPJ zone scattered around the downtown road network.

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